

High Gain DC-DC Converter with Coupled Inductor for Photovoltaic Applications

Nimitha Gopinath¹, Aswathi S², Dr. Sheela S³

PG Student, Dept. of EEE, NSS College of Engineering, Palakkad, Kerala, India¹

PG Student, Dept. of EEE, NSS College of Engineering, Palakkad, Kerala, India²

Professor, Dept. of EEE, NSS College of Engineering, Palakkad, Kerala, India³

ABSTRACT: Use of renewable energy is increasing day by day. Among them solar power is abundantly used nowadays. This results in the requirement of higher DC-DC voltage conversion for increasing output. Due to the lower voltage gain of various step up converters available, the efficiency of renewable systems are limited. This paper presents a switched coupled inductor dc-dc converter with high gain of 10. The designed circuit is simulated by MATLAB Simulink model and the results were verified by successfully building a prototype.

KEYWORDS: Photovoltaic (PV), DC-DC Converter, Switched coupled inductor

I. INTRODUCTION

Photovoltaic (PV) sources plays an important role in the world's energy scenario and have potential to become the biggest contributions to the electricity generation among all other renewable energy sources by year 2050 because of its abundant availability[1]. The block diagram of photovoltaic system is shown in Fig 1.

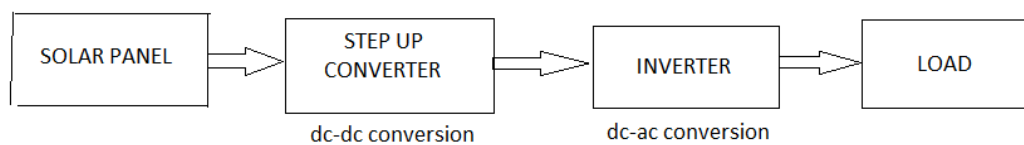


Fig 1 Block diagram of photovoltaic system

DC output of solar panel is fed to step up converter for boosting the output voltage. This is further converted to ac and fed to load. Here DC to DC converter plays an important role in determining the overall output of the system. Overall output obtained will be more if dc-dc converter is capable of producing more dc output voltage. There are different types of step up converters available in market which includes interleaved boost converter, positive superliftluo converter, high step up nonisolated step up converter, quadratic boost converter etc. But the voltage gain of most of them are limited.

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II. RELATED WORK

1) Superliftluo converter

The voltage lift technique is a popular method that is widely applied in electronic circuit design [2]. The circuit diagram is as shown in Fig 2.

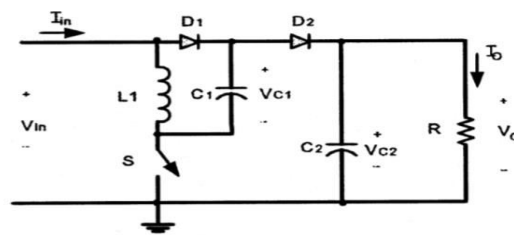


Fig 2 Superliftluo converter

It has a high efficiency and a high power density. In addition, Super-Lift Luo Converter has the ability to reduce ripple voltage and current. But the voltage gain is 4.

1) High step up non isolated DC-DC converter

It does not limit current during overload conditions even though it limits the starting inrush current[3]. The voltage gain is 9.6. The circuit diagram is shown in Fig 3.

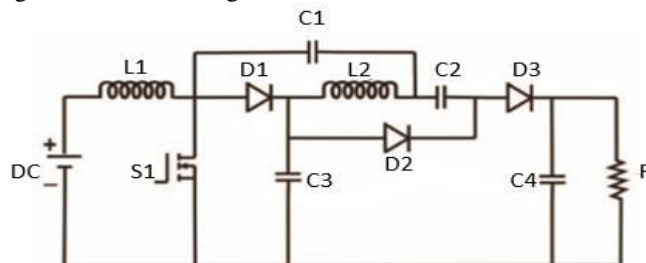


Fig 3 High step up non isolated DC-DC converter

2) Quadratic boost converter

Quadratic boost converter provides quadratic conversion ratio which offers wider conversion range[4]. As far as conversion efficiency is concerned, it is quite clear that a singlestage converter is always a better choice than a two-stage converter. Therefore, the quadratic converters are mainly used in applications where single-stage converters are required. The circuit diagram is shown in Fig 4.

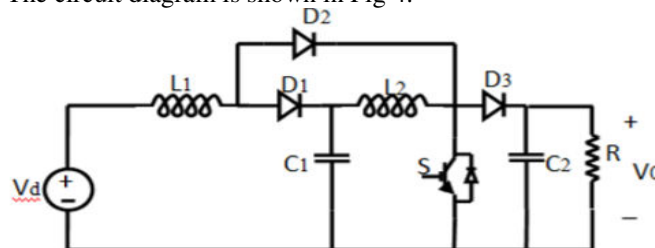


Fig 4 Quadratic boost converter

Even though it possess many advantages, it provide voltage gain of only 3.9.

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Due the low voltage gain of the available converters, a new converter which is capable of high voltage conversion is to be analysed. There arises the importance of switched coupled inductor DC- DC converter.

III. SWITCHED COUPLED INDUCTOR DC-DC CONVERTER

Circuit diagram of the topology is as shown in Fig 5.

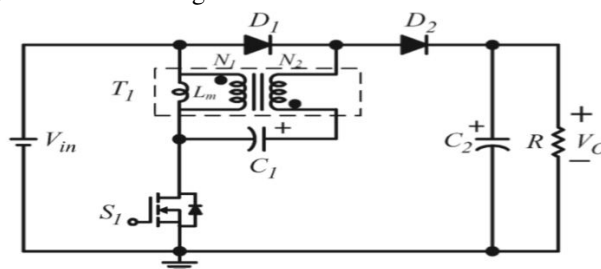


Fig 5 Switched coupled inductor DC-DC converter [3]

It consist of diode D_1 and D_2 , coupled inductor, switch S_1 , magnetizing inductor L_m , capacitor C_1 , C_2 and a resistive load. The components in the converter are assumed to be ideal and capacitor value is large to withstand the high voltage [5]. For obtaining high gain, turns ratio is taken as 1:3. The magnetizing inductance is integrated into the primary winding N_1 of coupled inductor T_1 . Parasitic resistance and the capacitance of the active switch and leakage inductance are neglected. Operation of circuit consists of two modes. Mode I is shown in Fig 6.

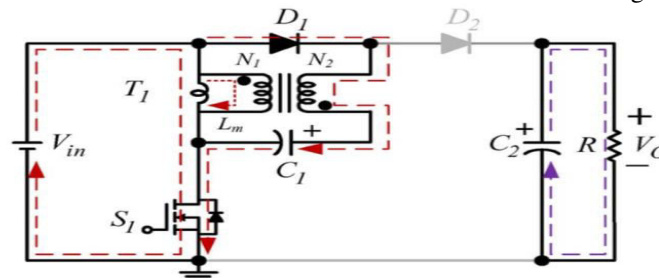


Fig 6 Mode I [5]

Switch is kept in on position as shown in mode I. Here D_2 will be reverse biased and D_1 will be forward biased. Voltage passes to S_1 through T_1 and a part passes through D_1 , secondary winding of coupled inductor N_2 and charges C_1 . This mode is called energy storage mode.

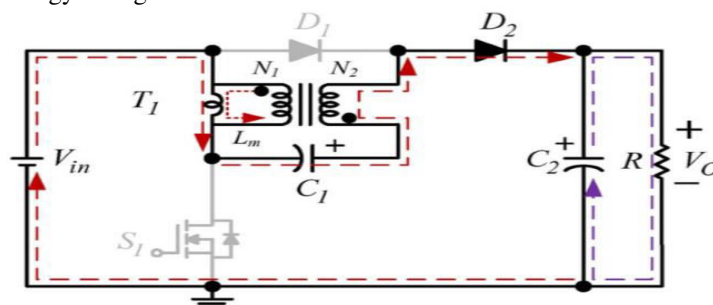


Fig.7 Mode II [5]

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In mode II switch will not be a part of the circuit (Fig 7). D1 will be reverse biased and D2 will be in conduction mode. Therefore, the source V_{in} , L_m , C_1 and N_2 winding are found to be in series and they charge the capacitor C_2 and the load. Hence this mode can be considered as energy releasing mode. So the total voltage conversion ratio = 1 + voltage across T1 + Voltage across C1 + voltage across D2

$$\begin{aligned} \text{Voltage conversion ratio} &= 1 + \frac{D}{1-D} + \frac{1+n}{1} + \frac{nD}{1-D} \\ &= \frac{2+n-D}{1-D} \end{aligned}$$

A comparison was made between various converters available with switched coupled inductor dc-dc converter on the basis of voltage gain is shown in Table 1.

Table 1
Comparison of various boost converters

Converter	Input voltage	Output voltage	Gain
Quadratic boost converter	12 V	47 V	3.9
Positive superliftluo converter	12 V	50 V	4.1
High step up non isolated DC –DC converter	12 V	116 V	9.6
Switched coupled inductor DC-DC converter	12 V	120 V	10

IV. SIMULATION AND EXPERIMENTAL RESULTS

The Coupled inductor boost converter was analysed by MATLAB Simulink model. The circuit parameters for the simulation are listed in Table 2.

Table 2
Parameters and their values

PARAMETERS	VALUES
Input voltage	12V
Output voltage	120V
Switching frequency	50Hz
Turns ratio of coupled inductor	1:3
Magnetising inductance	23uH
Leakage inductance	0.32uH
Capacitor 1	100uF
Capacitor 2	22uF
Duty cycle	0.56
S1	IRF540
D1	BYQ2BE
D2	MUR860

The steady state behaviour of the switched coupled inductor boost converter can be analysed by open loop MATLAB Simulink model. Fig.8 shows the simulink block diagram of a switched coupled inductor step up converter.

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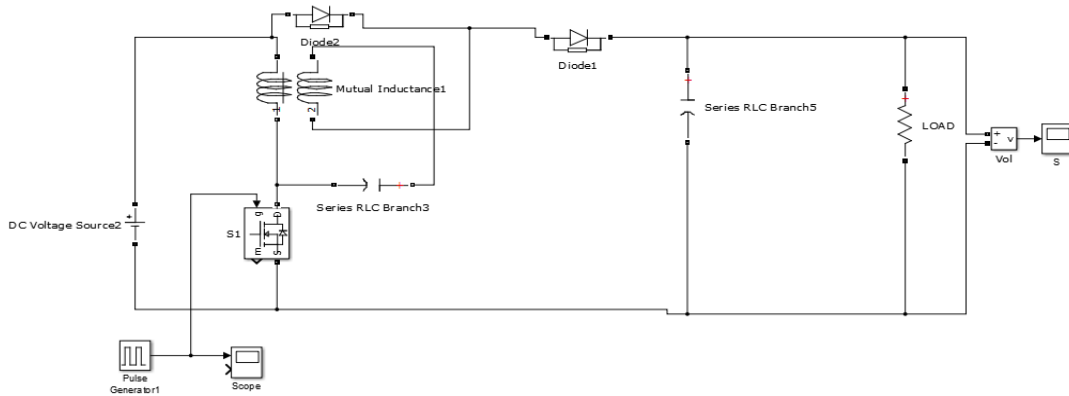


Fig 8 MATLAB/SIMULINK model of Converter

Here series RLC branch is used a capacitors and load is selected as resistive. Pulse generator provide gating pulses to the switch. Fig.9 illustrates the output voltage of the converter. The curve represents the boosted output voltage with a value of 120V.

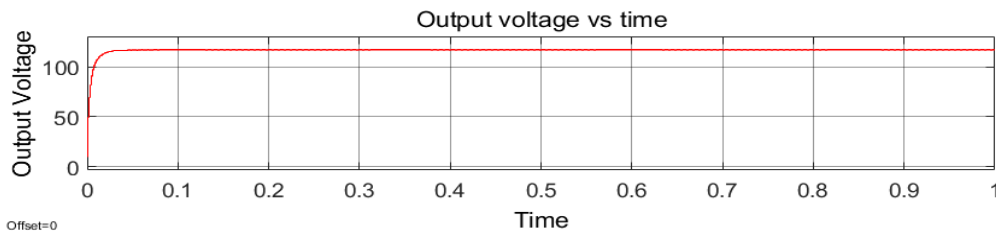


Fig 9 Output voltage of Switched coupled inductor dc-dc converter

In order to verify the circuit operation and confirm the simulation results a prototype is built and lab tested.

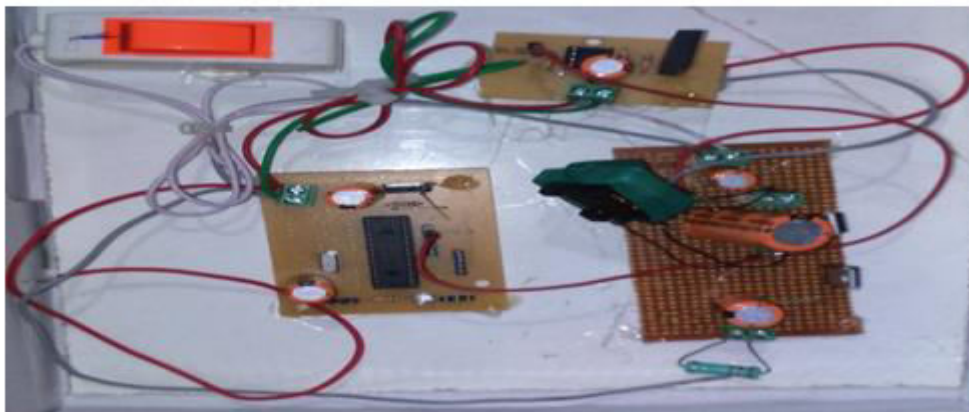


Fig 10 Experimental prototype

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The input to the converter is provided from a 12V battery and is regulated by using LM7805. The controller is also supplied from the battery. The supply to the driver is provided through a 230/12 V adapter. Driver IC is selected as UCC27322 and controller IC is dsPIC30F2010. The overall hardware structure is shown in Fig 10.

V. CONCLUSION

Compared to basic converter topologies, switched coupled inductor dc- dc converter offers higher gain of value 10. The leakage inductor energy of the coupled inductor can be recycled and directly output to the load. This increases the power conversion efficiency. Also, this converter consists of few components resulting in compact size and a high power density can be achieved. All these can be efficiently utilized in photovoltaic applications. The designed circuit is simulated by MATLAB Simulink model and the results were verified by successfully building a prototype.

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